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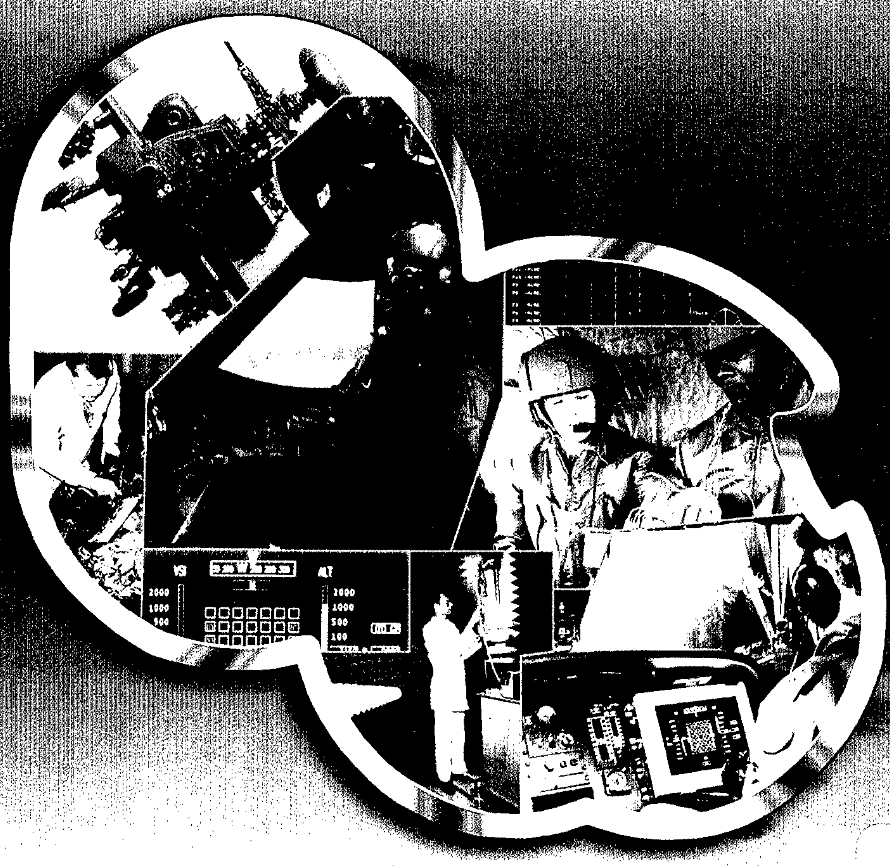
# Noise Attenuation in HALO Vertical Wind Tunnel Training

by Dale A. Ostler, Paul A. Cain, and Elmaree Gordon (USAARL) and Eric W. Fallon (Womack Army Medical Center, Fort Bragg, NC)



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The Vertical Wind Tunnel (VWT) at Ft. Bragg, NC is one of the Army's training grounds for High Altitude Low Opening (HALO) parachute jumpers. Due to the nature of the operation (i.e. jet engine and high wind stream) personnel using the VWT are exposed to steady-state noise levels in excess of 120 dBA SPL (sound pressure level). These levels exceed the safe noise exposure limits stipulated in DA PAM 40-501 even when double hearing protection is worn; therefore, time limits on noise exposure must be enforced. These time limits substantially curtail training efforts and impact military readiness status. Efforts have been made to increase the attenuation provided by the helmets worn in the VWT. An innovative approach was used to measure the at-the-ear noise levels under five different parachutist's helmets in the VWT. Subsequently, an estimate was made to determine the maximum allowable time of noise exposure. Results suggest that one of the helmets provides superior hearing protection to the others, thus allowing sufficient training time in the VWT. Application of these results and recommendations will be discussed.

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## Introduction

The Vertical Wind Tunnel (VWT) at Fort Bragg, North Carolina, is the Army's only flight simulator for High Altitude Low Opening (HALO) parachute jumpers. It is an octagon-shaped chamber about two-stories high housed in a three-story building. Powered by a 3600-horsepower jet engine, the VWT is capable of creating wind velocities in excess of 160 miles per hour (240 feet per second). The wind stream is contained in an area approximately 15 to 20 feet in diameter. The openings in the floor and ceiling in the center of the room, through which the wind stream moves, are covered by a net of ropes and the floor opening is bounded by padded mats. Additional netting forms a hanging canopy from the ceiling to about 10 feet above the floor and prevents the jumper from being thrown out of the wind stream. The HALO jumpers, dressed in an appropriate flight suit and helmet, enter the wind stream from the perimeter of the room. Figure 1 is a photograph of a HALO jumper in simulated flight in the VWT. Many hours of hard work are required in the VWT to master the fundamentals of the intricate procedures involved in this military operation in a safe manner. Even more time in the VWT is required of the Military Free Fall Instructors (MFFI) who train the HALO candidates.

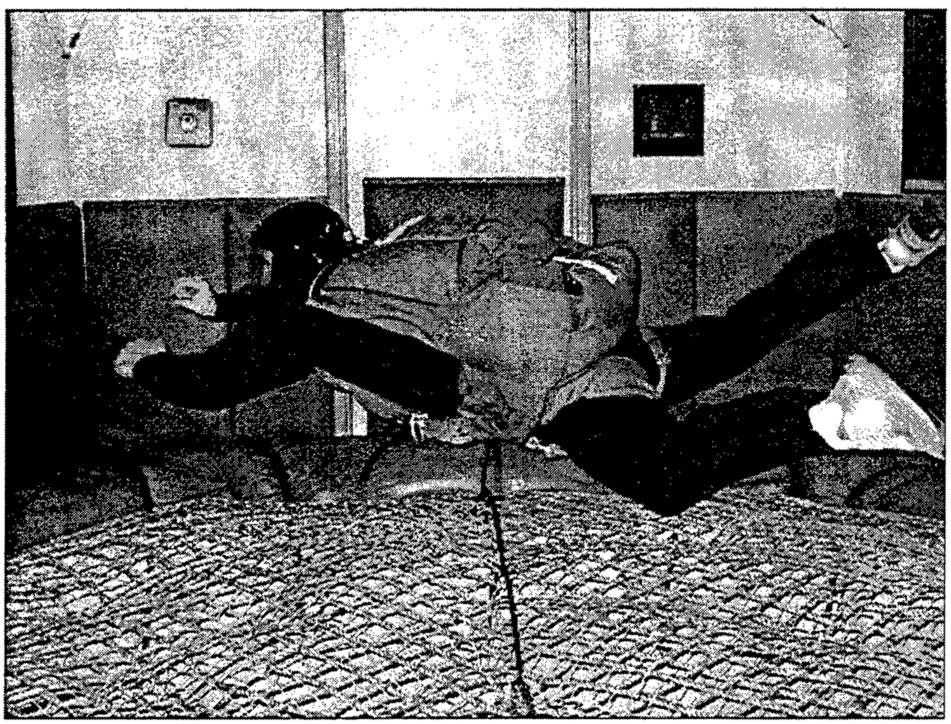

Figure 1. A HALO jumper in simulated flight in the Vertical Wind Tunnel.

Due of the nature of the operation, personnel using the VWT are exposed to extremely loud levels of noise. The primary source of the noise is the jet engine located directly overhead directly through the ceiling opening of the wind tunnel chamber. The secondary noise source is

the high wind velocity and its associated turbulence. A previous estimate of the noise levels in the VWT indicated that the overall dB A-weighted (dBA) average is in excess of 121 dBA SPL (sound pressure level)[1]. This level of noise clearly exceeds the safe noise exposure limits stipulated in Department of the Army Pamphlet (DA PAM) 40-501 (1998) even when wearing double hearing protection (circumaural muffs and earplugs) and requires that time restrictions be observed when exposed to these exceptionally hazardous levels of noise. Consequently, an estimate of the permissible exposure time to this level of noise when using double protection (the Gentex HGU-55/P and the E•A•R earplug) revealed that the maximum allowable time limit for safe exposure was 3.2 hours (190 minutes) per day[2].

Adhering to this time constraint makes it difficult for personnel involved in HALO jump training to acquire the necessary skills. Currently, training in the VWT is being conducted with an authorized waiver for this time limit. Training in the VWT, therefore, places the HALO personnel (particularly the MFFI) at serious risk of permanent hearing damage and poses a significant threat to the health and well-being of the fighting force.

Since the estimate of permissible exposure time was made, U.S. Army Special Operations Command (USASOC), the primary user of the VWT, has made efforts to extend the amount of time that can be spent in the VWT by enhancing the noise attenuation properties of the various helmets used in this flight simulator. Specifically, modifications were made to two helmets, the GENTEX® HALO Lightweight Parachutist Helmet (Figure 2) and the ParaSport® Z1 Full Face Helmet (Figure 3). The HALO Lightweight Parachutist Helmet is manufactured by GENTEX Corporation® and is designed for impact protection. The Z1 Full Face Helmet is manufactured by the Italian company, ParaSport Italia®, and serves as a full-face helmet with a flip-up visor. This helmet is designed for impact and face protection. USASOC sent both of these helmets to Oregon Aero for modification to increase their sound attenuating characteristics. Oregon Aero modified both helmets by placing a pair of SoftSeal™ earcups in each helmet. The SoftSeal™ is a soft-sided earcup with an integral earcup seal. The inside of the earcup is filled with proprietary dense memory foam.

This study was in response to a request from USASOC to measure the effectiveness of these above-mentioned helmets in reducing the at-the-ear noise exposure levels in an effort to increase the amount of safe permissible time the HALO jumper could spend in the VWT. USASOC also requested that a fifth helmet modification be used in the evaluation. This configuration is the addition of active noise reduction (ANR) system to the GENTEX® HALO Lightweight Parachutist Helmet. On site measurements in the VWT were believed necessary to take into account the effect of the force of the wind stream against the helmet that could not be accounted for in a laboratory setting.

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[1] Unpublished data reported by Industrial Hygiene (IH), Department of Preventive Medicine, Womack Army Medical Center (AMC), Fort Bragg, NC.

[2] Unpublished data from Hearing Conservation Program, U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) as reported by Department of Preventive Medicine, Womack AMC, Fort Bragg, NC.

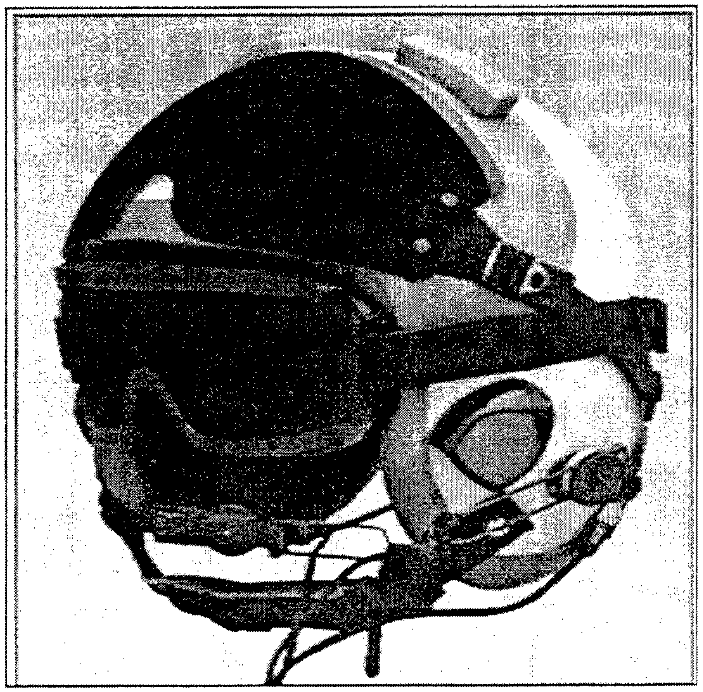

Figure 2. GENTEX® HALO Lightweight Parachutist Helmet

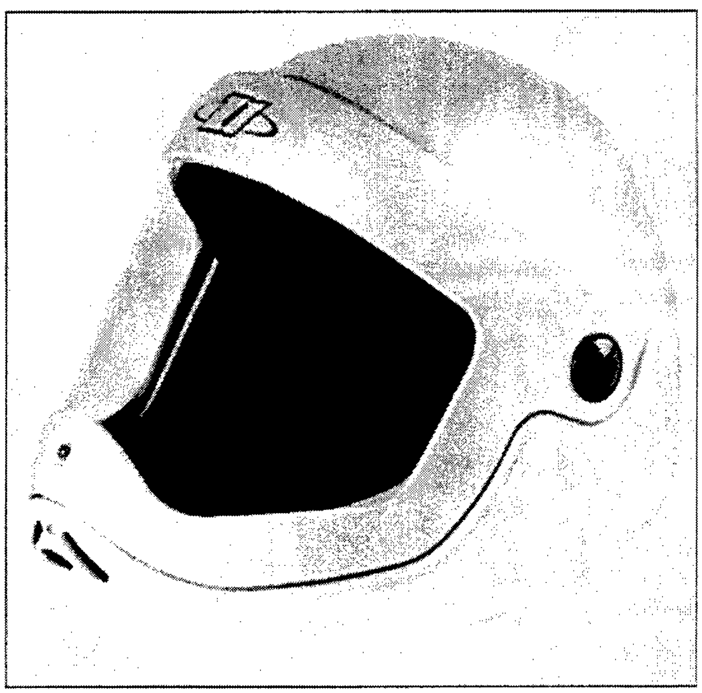

Figure 3. ParaSport® Z1 Full Face Helmet.

# Method

As this was a noise level measurement survey performed on site in a military duty environment, the experimental design reflects the circumstances unique to this situation. Noise level measurements were made inside both earcups (right and left) of each helmet while worn by a HALO jumper during actual flight simulation in the VWT.

## Equipment

Noise level measurements were made using a data acquisition and recording system (Sony DAT recorder PC204A with a Brüel & Kjær (B&K) Acoustic Front End Type 5968) which was padded and secured in the jumper's parachute container in lieu of the standard dummy parachute (see Figure 4). A lightweight miniature microphone (Knowles, Model 1832) was secured under the helmet at each ear canal opening by placing a Silaflex™ formable ear plug in the ear canal and mounting the miniature microphone on the plug (see Figure 5). A cable, secured under the flight suit, was used to connect each microphone with to the data acquisition system.

The helmets used in this noise survey were:

1. GENTEX® HALO Lightweight Parachutist Helmet with no modification (HALO Standard).

2. GENTEX® HALO Lightweight Parachutist Helmet with SoftSeal™ (HALO Modified).

3. GENTEX® HALO Lightweight Parachutist Helmet with ANR (HALO with ANR).

4. ParaSport® Z1 Full Face Helmet with no modification (Z1 Standard).

5. ParaSport® Z1 Full Face Helmet with SoftSeal™ (Z1 Modified).

A single noise level measurement, lasting approximately 2 minutes, was made for each helmet configuration. Specifically, after the recording equipment was placed in the parachute pouch and connected to the microphones mounted in the jumper's ear canals, the system was activated and the pouch was secured and strapped to the jumper's back in the customary manner. The jumper then donned one of the five helmets, entered the wind stream, and performed simple flight maneuvers for approximately 2 minutes while the noise recording was made. After exiting the wind stream, a check was made to verify that the noise sample was recorded. The jumper then replaced the helmet just worn with another helmet and performed similar flight maneuvers to those made in the first recording while another wind stream recording was then made. This process was repeated for each of the five helmet conditions. Noise recordings for each condition lasted approximately 2 minutes to ensure that the subsequent analysis was based on consistent level recordings and that the recording could be examined for any inconsistencies.

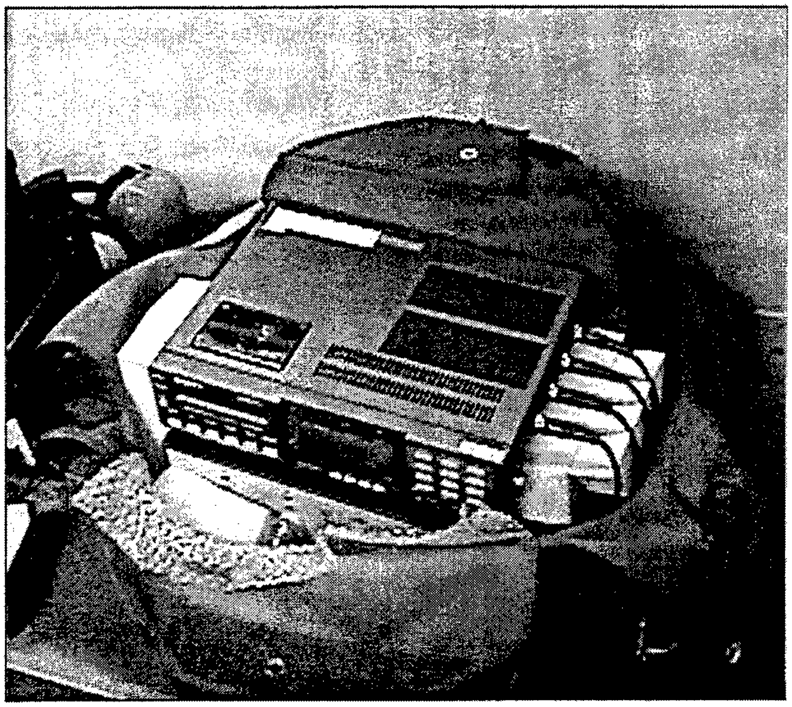

Figure 4. The Sony DAT recorder, PC204A, with the B&K Acoustic Front End, Type 5968, in the jumper's parachute pouch.

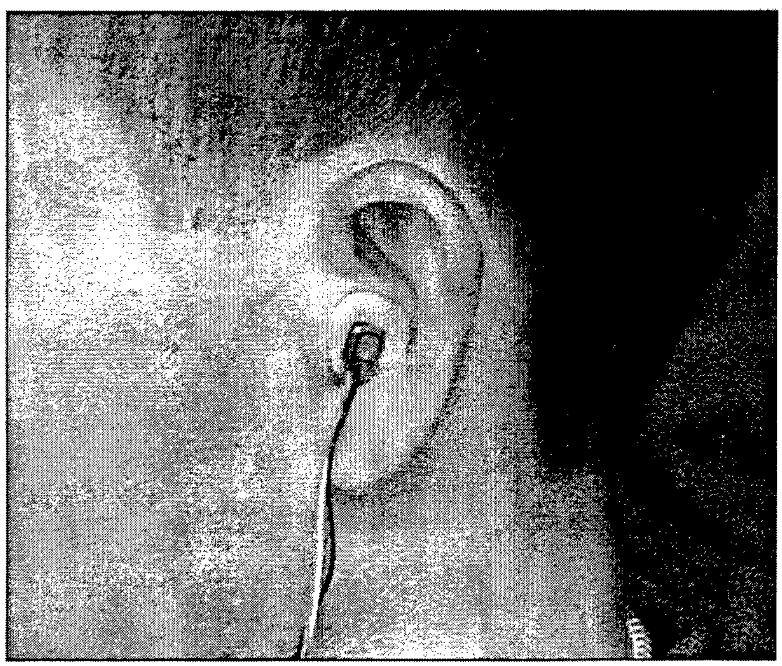

Figure 5. Knowles, Model 1832, miniature microphone mounted on Silaflex™ formable ear plug in the ear canal.

Two free-field noise level measurements using the same data acquisition and recording system also were made in the VWT, in accordance with (IAW) Military Standard (MIL-STD) 1474D. One of these recordings was of the wind stream noise (WSN) and the other was of the perimeter noise (PN) outside of the wind stream. In lieu of the miniature microphones, however, two B&K ½-inch microphones (Type 4192) fitted with a B&K nose cone, Type UA0386 (required for measurements in airstreams with high wind speeds), were used to make a two-channel recording for the WSN and the PN. Each noise sample was recorded for a minimum of 2 minutes. For the WSN measurement, the microphones were held in the wind stream by having the HALO jumper hold one microphone in each hand and lean into the wind stream from the edge (see Figure 6). For the PN measurement, the microphones were positioned at the perimeter of the VWT room outside of the wind stream but still inside the wind tunnel chamber (see Figure 7).

### Subjects

Due to the time constraints encountered during the day of the recording, only one jumper was used to make the noise level recordings. The volunteer participant was required to be a qualified HALO jumper. IAW U.S. Army Medical Research and Materiel Command (MRMC) Regulation 70-25 (1990), Appendix F, paragraphs "g" and "h," exemption from Human Use Informed Consent was granted by the Chair of the USAARL Human Use Committee due to the fact that the jumper was involved in his routine duties.

## Results

The analysis of the noise recording consisted of extracting several samples from each recorded segment and averaging the noise levels by third-octave band center frequencies. Multiple samples were taken so that the average noise level for each condition would be representative of the actual noise level. These sample extractions were taken from segments of the noise recording that were relatively free of anomalies or obvious inconsistencies in the recording. The third-octave band center frequency noise levels were converted to one-octave band center frequency data. The A-weighted average for each condition was also extracted from the noise recordings. The appendix contains the third-octave band center frequency and A-weighted noise levels (in dB).

Figure 8 shows the average third-octave levels for WSN and PN, while Figure 9 shows the average third-octave levels for the at-the-ear noise for the five helmet configurations. Figures 10 and 11 show these same results, respectively, using one-octave data. The A-weighted WSN average was 122.5 dBA SPL while the PN A-weighted average was 115.8 dBA SPL. It can be noted from Figures 8 and 10 that the maximum energy for the WSN comes from the frequency region between 125 Hz and 1 k Hz.

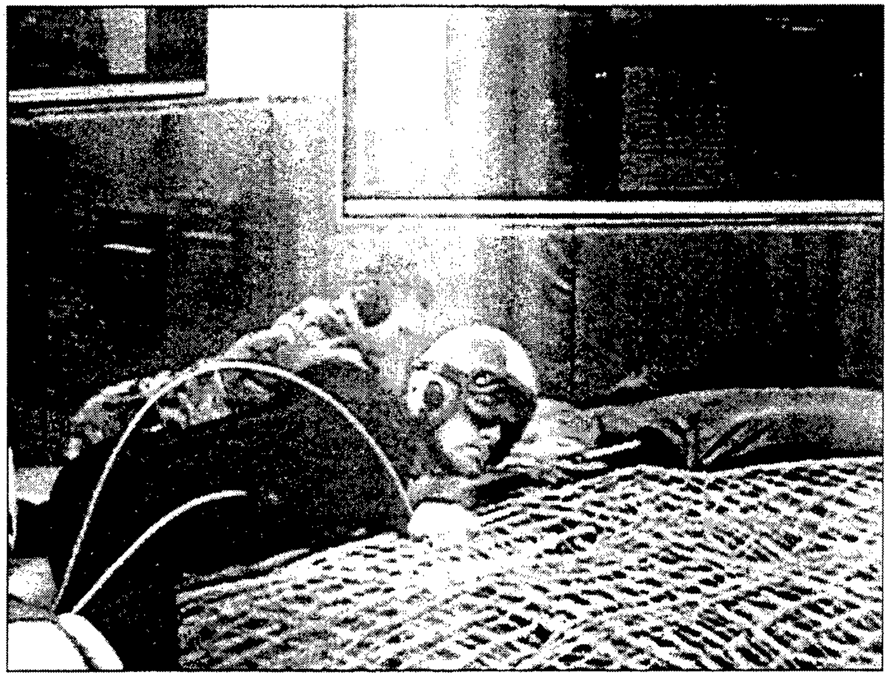

Figure 6. Wind steam noise measurement being taken by holding two B&K microphones (with noise cones) in the wind stream (subject in foreground).

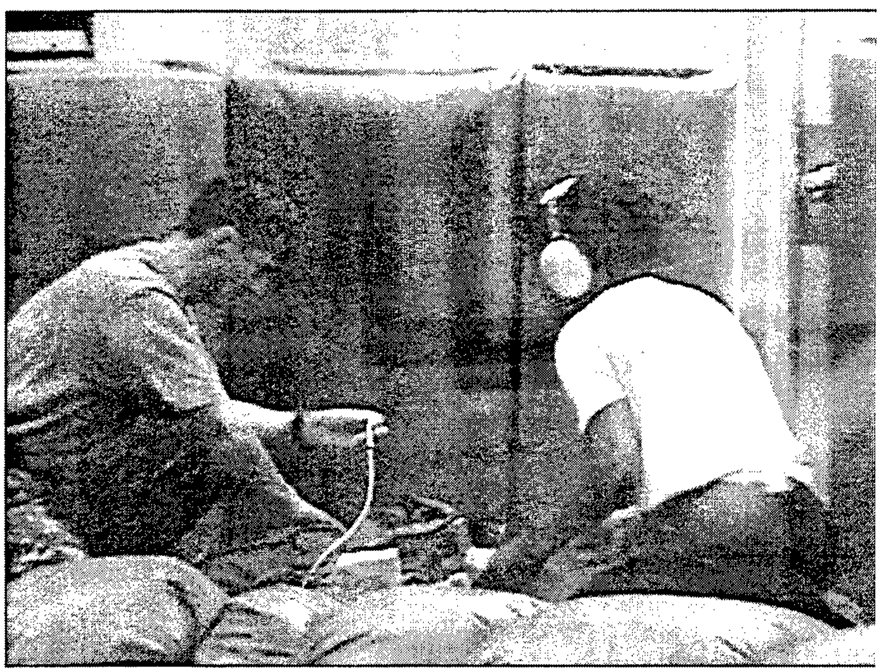

Figure 7. Perimeter noise measurement being taken by holding the B&K microphone inside the wind-stream chamber but outside of the wind stream.

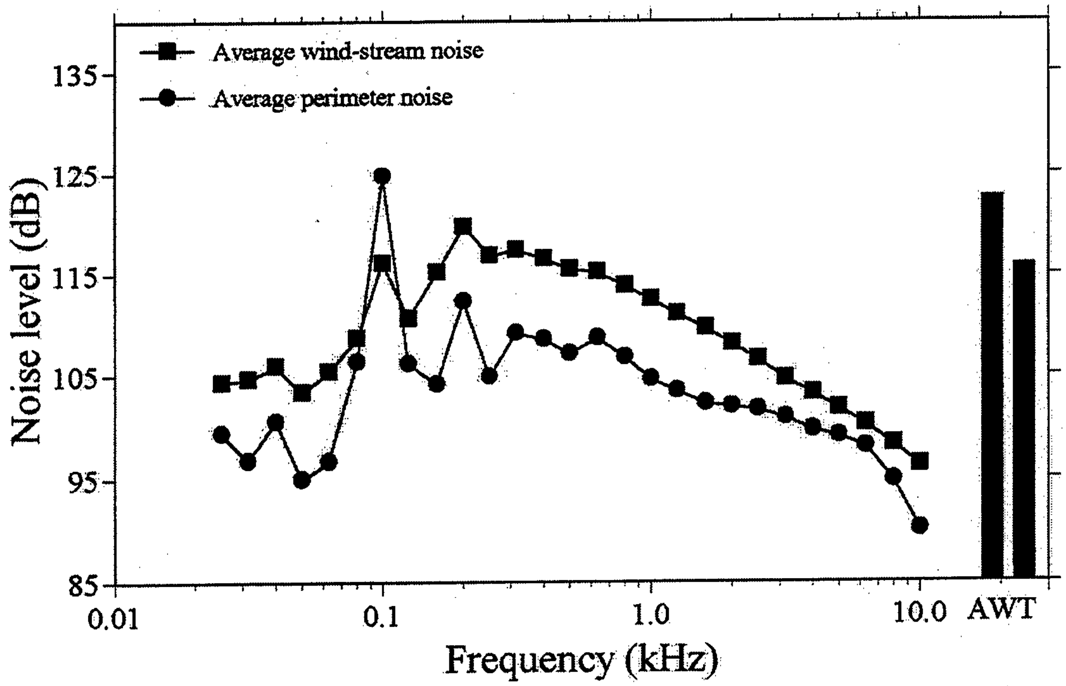


Figure 8. Average third-octave free-field noise levels in the Vertical Wind Tunnel.

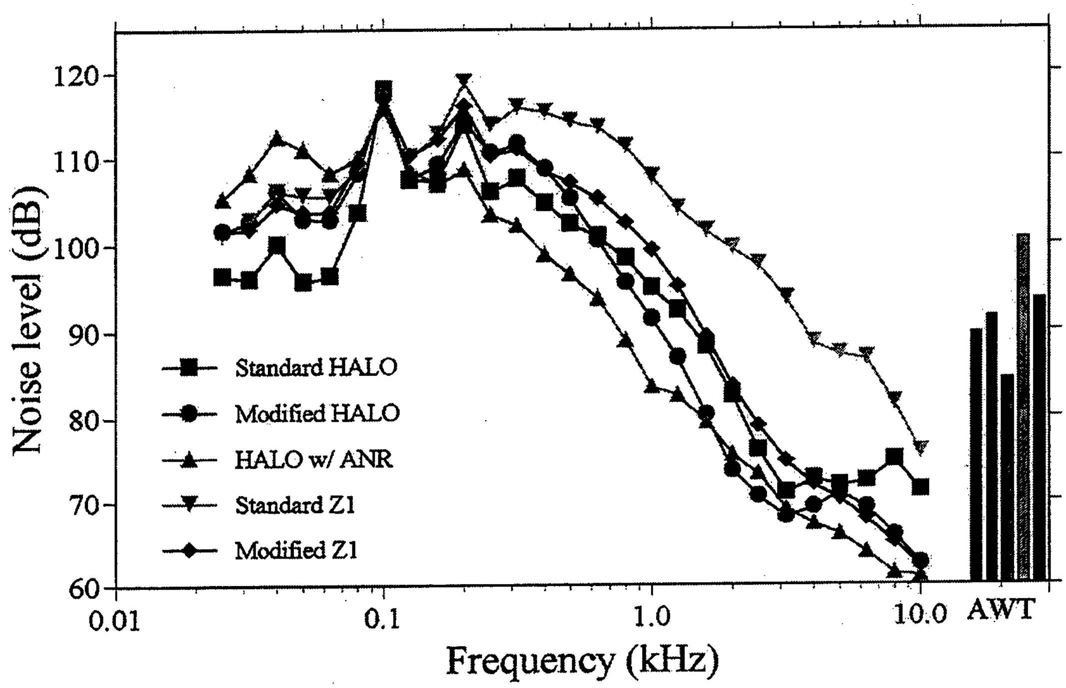


Figure 9. Average third-octave at-the-ear noise levels for five helmet configurations in the Vertical Wind Tunnel.

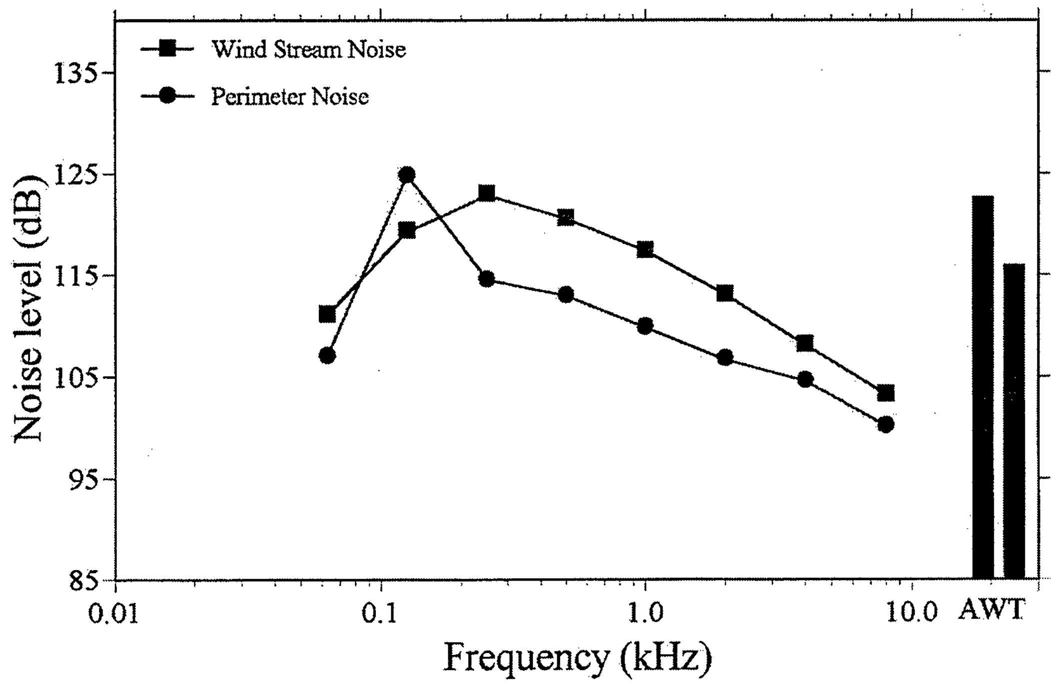


Figure 10. Average one-octave free-field noise levels in the Vertical Wind Tunnel.

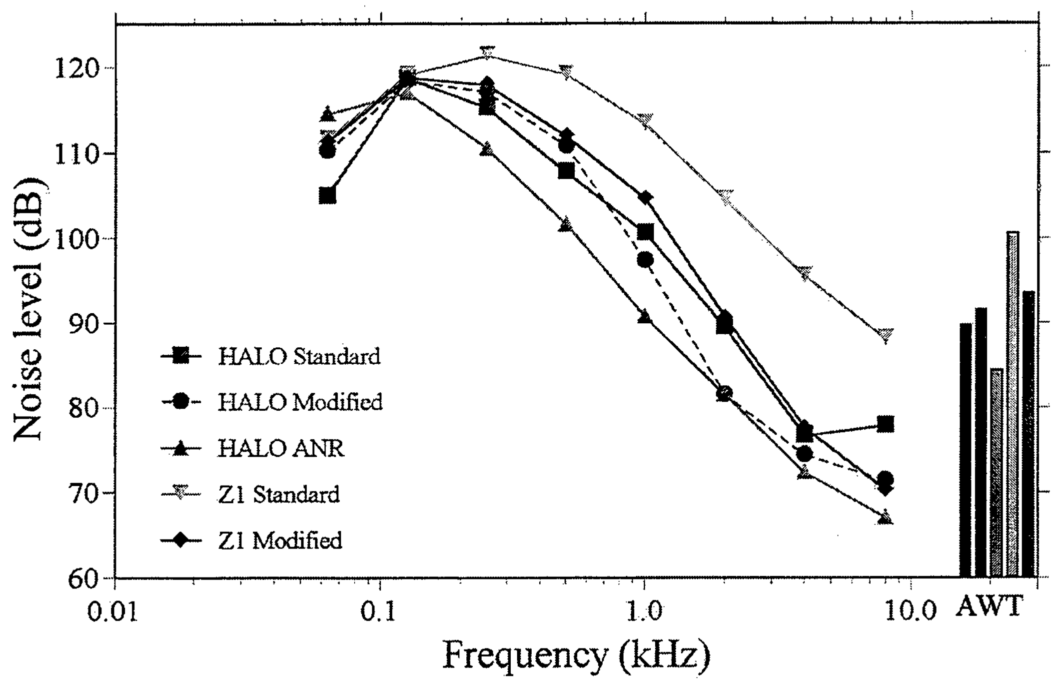


Figure 11. Average one-octave at-the-ear noise levels for five helmet configurations in the Vertical Wind Tunnel.

From Figures 9 and 11, it can be seen that the HALO Lightweight Parachutist Helmet with ANR allows the lowest at-the-ear noise exposure (i.e., the greatest noise attenuation). The A-weighted at-the-ear noise level for this helmet configuration is 105.5 dB SPL. The Standard HALO helmet allows the next lowest at-the-ear noise exposure (110.1 dBA SPL) and the Modified HALO helmet allows the third lowest at-the-ear noise exposure (111.7 dBA SPL). The Modified Z1 helmet allows 113.3 dBA SPL average at-the-ear noise level, while the Standard Z1 helmet allows 119.2 dBA SPL average at-the-ear noise level. A closer inspection of Figures 9 and 11 reveals that the distinction for the noise exposure between the Standard HALO helmet and the Modified HALO helmet lies in the frequency range of noise that is attenuated. When compared against each other, the former appears more protective at 250 and 500 Hz, while the later appears more protective above 500 Hz. The HALO helmet with ANR allows the least noise exposure at all frequencies except 63 Hz and at 2 k Hz, where it is similar to the modified HALO helmet.

## Discussion

USASOC's primary interest in obtaining these noise measurements was to determine if the modifications made to these helmets would allow the HALO jumpers to extend the amount of time they could safely spend in the VWT. Using the average at-the-ear octave band noise levels for each helmet configuration (Figure 7) as the noise exposure level and the average attenuation values of the E•A•R earplug (Royster et al., 1996)[3] as the HPD attenuation values, we estimate the safe permissible noise exposure times as shown in Figure 12.

Figure 12 clearly shows the superiority of the HALO helmet with ANR over the other helmet configurations in protecting the jumper from the hazardous effects of the noise. This helmet allows 10.1 hours (605 minutes) per day in the WSN. From Figures 9 and 11, it can be observed that the frequency region afforded the greatest protection by the HALO helmet with ANR over the other helmets is from 250 Hz to 1 kHz, which, as noted previously, is the frequency region with the greatest hazardous noise levels.

The Standard HALO helmet allows 3.9 hours (235 minutes) per day of exposure in the WSN. This allows just slightly more time (about 45 minutes more) in the VWT than was allowed based on the results of the previously reported time-limit estimate conducted by U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM), which limited the permissible WSN exposure to just less than 3.2 hours (190 minutes) per day.

[3] The average attenuation values for the E•A•R earplug are from Subject-Fit data obtained from four different laboratories around the country participating in a subject-fit study and are representative of the attenuation values that would likely be obtained by the user in the field (i.e., a HALO jumper in the VWT).

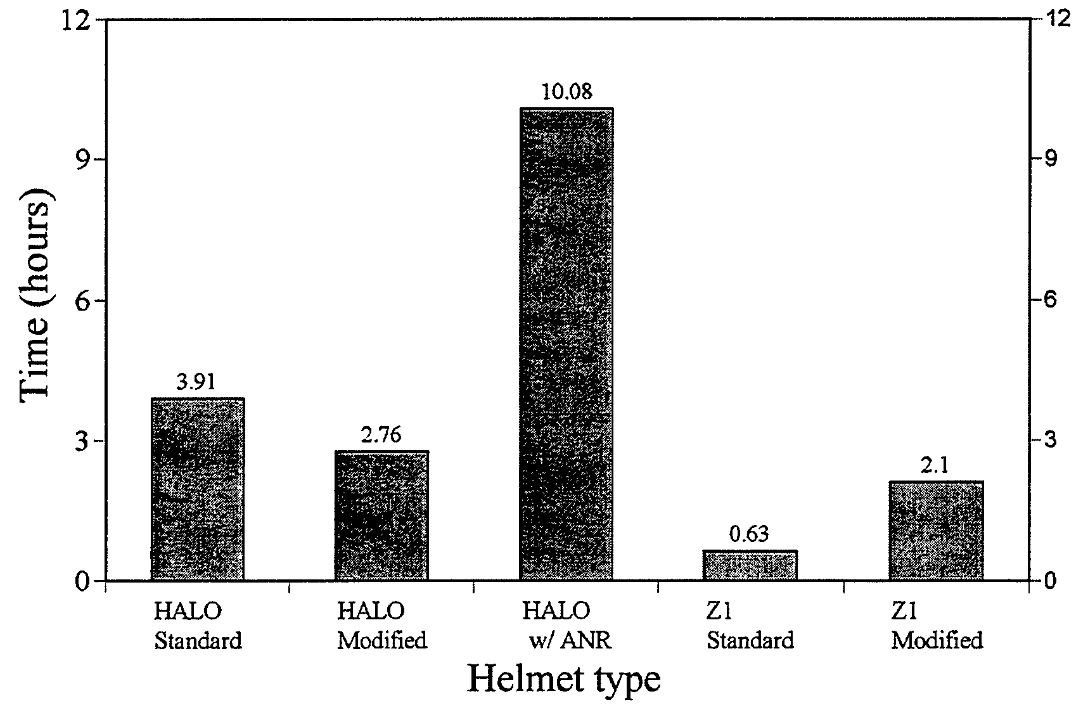


Figure 12. Permissible noise exposure time limits by helmet condition for double hearing protection (helmet plus E•A•R earplug) in the VWT.

Surprisingly, the data for the Oregon Aero modified HALO helmet allow even less time in the WSN (2.8 hours/day) than the unmodified HALO helmet (3.9 hours/day). No reasonable explanation is apparent for this unanticipated result. It is possible that this is an outlier, in which case, additional measurements would be warranted. It also is possible that further adjustments or modifications to his helmet may be needed.

The time limits for the Z1 helmets are just more than 0.5 hour for the standard helmet and just over 2 hours/day for the Oregon Areo modified helmet. The advantage of these helmets, as previously mentioned, is the added face and impact protection they afford.

In applying these data for time limits, it must be remembered that the time limits are for 24-hour periods. That is, if one is in the WSN up to the maximum time allowed by these data (i.e., 10.1 hours using the HALO helmet with ANR in combination with the E•A•R plugs), then the remaining time in the 24-hour period must be spent outside of the VWT at levels less than the hazardous noise level (85 dBA). This is an important point as it is possible that HALO jumpers, especially the MFFI, can spend several hours at a time in the VWT.

## Conclusion and recommendations

Even though this report is based on noise exposure measurements of only one HALO jumper, the authors believe that the overall data comparisons are sound. That is, the HALO helmet with ANR provides the lowest at-the-ear noise level followed by the HALO standard helmet, and so forth, as shown in Figures 9 and 11. We therefore recommend that the HALO with ANR helmet be the helmet-of-choice for use in the VWT. This helmet, of course, must always be used in combination with the E•A•R earplug for these time limits to apply. It is reasonable to allow that the HALO jumper may use one of the other helmets evaluated in this study (always in combination with the E•A•R earplug) as long as there is strict adherence to the time restrictions indicated. The result of following this recommendation will be increased hearing protection and less fatigue than would be attained without adequate hearing protection. These two advantages can translate into reduced incidences of noise induced hearing loss as well as increased performance over extended periods of time in the VWT, respectively. Caution is urged in attempting to apply these data to actual free-fall jumping, which, it is presumed, would be less noise hazardous due to the absence of the primary noise source—a jet engine.

It should be noted that no statistical analysis on this data could be made because of the small sample size. Therefore, if greater statistical accuracy or power is desired, we recommend additional noise exposure/attenuation measurements be made. We recommend that this be accomplished in the VWT by taking measurements under each helmet configuration on a minimum of 10 HALO qualified jumpers in the same manner as was done in this current study.

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## Appendix

Average third-octave center frequency and A-weighted noise levels (dBA) for all conditions in the Vertical Wind Tunnel.

Third-octave center frequency and A-weighted noise levels (dBA) for all conditions in the Vertical Wind Tunnel.

| | Third-octave center frequency (Hz) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Condition** | **25** | **31.5** | **40** | **50** | **63** | **80** | **100** | **125** | **160** | **200** | **250** | **315** | **400** | **500** |
| Perimeter Noise | 89.4 | 88.5 | 93.2 | 90.7 | 93.0 | 103.3 | 123.0 | 104.7 | 104.3 | 116.3 | 105.7 | 110.4 | 107.8 | 107.7 |
| Perimeter Noise | 89.6 | 87.7 | 93.1 | 88.5 | 92.8 | 104.6 | 123.2 | 104.6 | 103.6 | 113.4 | 104.9 | 108.0 | 107.8 | 108.1 |
| Perimeter Noise | 101.2 | 98.3 | 102.4 | 96.5 | 98.0 | 107.0 | 125.7 | 107.1 | 103.5 | 112.6 | 104.1 | 108.2 | 106.2 | 106.3 |
| Perimeter Noise | 100.9 | 97.7 | 101.5 | 95.7 | 98.5 | 108.1 | 126.0 | 106.4 | 103.9 | 112.9 | 104.6 | 108.8 | 107.0 | 107.4 |
| Perimeter Noise | 102.8 | 100.6 | 103.8 | 96.5 | 96.7 | 105.3 | 123.9 | 105.7 | 105.1 | 111.1 | 104.9 | 108.4 | 108.9 | 107.4 |
| Perimeter Noise | 103.5 | 100.1 | 102.8 | 96.2 | 97.0 | 106.0 | 123.8 | 106.8 | 105.6 | 111.0 | 104.5 | 109.2 | 110.5 | 107.6 |
| Perimeter Noise | 102.7 | 99.9 | 103.8 | 97.3 | 97.9 | 107.4 | 125.8 | 106.8 | 103.2 | 110.7 | 105.2 | 110.6 | 110.8 | 106.0 |
| Perimeter Noise | 103.9 | 100.4 | 103.6 | 97.6 | 98.9 | 108.7 | 126.1 | 106.9 | 103.8 | 110.6 | 104.7 | 108.9 | 109.0 | 106.6 |
| **Average PN** | **99.3** | **96.7** | **100.5** | **94.9** | **96.6** | **106.3** | **124.7** | **106.1** | **104.1** | **112.3** | **104.8** | **109.1** | **108.5** | **107.1** |
| Wind Stream Noise | 101.2 | 97.9 | 100.0 | 97.0 | 97.4 | 102.4 | 116.1 | 107.7 | 112.7 | 119.5 | 116.5 | 120.5 | 118.6 | 116.5 |
| Wind Stream Noise | 99.8 | 99.6 | 100.2 | 99.1 | 101.7 | 109.5 | 113.1 | 107.2 | 117.9 | 122.5 | 117.5 | 115.1 | 114.0 | 112.2 |
| Wind Stream Noise | 108.1 | 110.6 | 116.3 | 111.7 | 117.1 | 113.2 | 116.7 | 114.3 | 114.2 | 118.2 | 115.9 | 117.0 | 117.0 | 116.9 |
| Wind Stream Noise | 109.5 | 111.9 | 112.5 | 112.3 | 113.3 | 114.6 | 117.9 | 115.8 | 115.7 | 118.5 | 116.4 | 116.8 | 116.3 | 116.4 |
| Wind Stream Noise | 99.3 | 98.0 | 99.9 | 93.9 | 96.8 | 102.8 | 115.7 | 108.6 | 115.6 | 118.4 | 118.4 | 118.3 | 117.3 | 116.2 |
| Wind Stream Noise | 101.4 | 98.1 | 100.2 | 96.9 | 97.7 | 102.6 | 116.6 | 107.9 | 112.8 | 119.7 | 116.8 | 120.8 | 118.7 | 116.7 |
| Wind Stream Noise | 99.0 | 99.3 | 98.9 | 98.4 | 103.1 | 110.3 | 113.4 | 107.3 | 118.5 | 122.6 | 116.9 | 114.7 | 114.3 | 113.0 |
| Wind Stream Noise | 113.5 | 118.8 | 117.4 | 115.6 | 114.4 | 113.9 | 117.4 | 113.8 | 114.5 | 119.6 | 114.9 | 116.2 | 115.1 | 114.4 |
| Wind Stream Noise | 111.8 | 113.2 | 113.9 | 113.3 | 113.6 | 113.6 | 117.7 | 114.6 | 114.6 | 119.2 | 115.8 | 116.2 | 116.2 | 116.0 |
| Wind Stream Noise | 99.4 | 98.1 | 100.0 | 94.3 | 97.4 | 103.1 | 116.0 | 108.9 | 115.7 | 118.6 | 118.7 | 118.5 | 117.9 | 116.7 |
| **Average WSN** | **104.3** | **104.6** | **105.9** | **103.3** | **105.3** | **108.6** | **116.1** | **110.6** | **115.2** | **119.7** | **116.8** | **117.4** | **116.5** | **115.5** |
| Standard HALO | 101.5 | 97.2 | 100.0 | 91.6 | 94.5 | 104.2 | 119.9 | 107.7 | 110.7 | 116.0 | 111.6 | 113.3 | 112.4 | 109.6 |
| Standard HALO | 98.1 | 94.0 | 95.0 | 86.4 | 91.2 | 102.5 | 122.7 | 106.0 | 103.8 | 110.9 | 100.3 | 104.3 | 103.9 | 102.7 |
| Standard HALO | 107.3 | 110.7 | 117.4 | 117.2 | 110.9 | 111.9 | 119.6 | 111.6 | 109.7 | 116.9 | 107.1 | 106.8 | 102.1 | 99.6 |
| Standard HALO | 109.3 | 112.1 | 117.1 | 117.1 | 111.6 | 111.5 | 121.2 | 111.6 | 109.9 | 115.9 | 107.1 | 107.0 | 102.5 | 99.4 |
| Standard HALO | 109.4 | 112.7 | 115.8 | 112.9 | 111.7 | 111.0 | 121.9 | 112.1 | 109.6 | 117.5 | 107.4 | 107.3 | 103.5 | 99.7 |
| Standard HALO | 101.6 | 94.1 | 95.6 | 91.1 | 92.6 | 102.9 | 124.3 | 108.4 | 105.1 | 112.4 | 102.1 | 107.5 | 101.7 | 99.9 |
| Standard HALO | 100.6 | 96.9 | 99.6 | 91.0 | 93.7 | 102.8 | 118.2 | 107.1 | 110.2 | 117.4 | 113.9 | 114.7 | 112.7 | 109.1 |
| Standard HALO | 84.9 | 82.2 | 87.7 | 80.1 | 84.8 | 97.1 | 113.5 | 103.2 | 107.0 | 112.3 | 108.0 | 109.9 | 108.4 | 106.5 |
| Standard HALO | 81.4 | 78.8 | 82.8 | 74.4 | 80.6 | 95.1 | 115.6 | 101.7 | 100.0 | 107.4 | 96.0 | 99.8 | 99.1 | 99.7 |
| Standard HALO | 94.3 | 101.1 | 109.1 | 108.3 | 105.0 | 105.5 | 112.6 | 105.9 | 104.7 | 112.2 | 101.8 | 102.6 | 98.6 | 97.0 |
| Standard HALO | 96.6 | 100.8 | 106.1 | 108.3 | 104.8 | 107.3 | 115.0 | 110.6 | 111.7 | 114.2 | 110.4 | 108.8 | 106.0 | 102.4 |
| Standard HALO | 95.8 | 101.3 | 105.0 | 104.8 | 105.4 | 108.0 | 116.0 | 112.3 | 112.2 | 115.5 | 110.6 | 109.7 | 106.3 | 103.3 |
| Standard HALO | 84.7 | 78.8 | 83.0 | 77.8 | 80.0 | 95.6 | 118.3 | 103.4 | 101.1 | 108.7 | 97.6 | 102.7 | 99.0 | 97.3 |
| Standard HALO | 83.6 | 82.6 | 85.9 | 78.7 | 82.4 | 94.5 | 111.7 | 102.1 | 106.7 | 114.8 | 110.4 | 110.9 | 109.0 | 106.3 |
| **Avg: Standard HALO** | **96.4** | **96.0** | **100.0** | **95.7** | **96.4** | **103.6** | **117.9** | **107.4** | **107.3** | **113.7** | **106.0** | **107.5** | **104.7** | **102.3** |

Third-octave center frequency and A-weighted noise levels (dBA) for all conditions in the Vertical Wind Tunnel.

| | Third-octave center frequency (Hz) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | 630 | 800 | 1k | 1.25k | 1.6k | 2k | 2.5k | 3.15k | 4k | 5k | 6.3k | 8k | 10k | AWT |
| Perimeter Noise | 109.3 | 106.0 | 103.8 | 103.7 | 103.2 | 102.8 | 102.6 | 101.9 | 99.9 | 98.7 | 98.8 | 95.4 | 89.2 | 116.1 |
| Perimeter Noise | 110.3 | 108.3 | 103.6 | 103.3 | 101.0 | 102.2 | 103.2 | 101.7 | 99.8 | 99.2 | 98.8 | 95.0 | 89.7 | 116.1 |
| Perimeter Noise | 106.0 | 103.9 | 102.4 | 101.8 | 101.0 | 100.8 | 100.8 | 100.8 | 100.1 | 100.3 | 99.7 | 96.0 | 89.6 | 114.7 |
| Perimeter Noise | 109.6 | 108.6 | 105.5 | 102.4 | 102.8 | 102.6 | 99.5 | 98.5 | 98.6 | 99.2 | 98.0 | 94.7 | 90.1 | 116.0 |
| Perimeter Noise | 109.1 | 107.3 | 105.6 | 104.0 | 102.9 | 102.2 | 102.5 | 101.0 | 99.9 | 98.8 | 97.5 | 94.3 | 90.5 | 115.9 |
| Perimeter Noise | 109.2 | 107.1 | 105.6 | 104.6 | 103.0 | 102.4 | 102.1 | 101.3 | 100.0 | 98.9 | 97.5 | 94.4 | 90.6 | 116.2 |
| Perimeter Noise | 107.6 | 105.9 | 105.5 | 103.6 | 101.7 | 101.2 | 101.3 | 100.8 | 99.2 | 98.3 | 97.1 | 94.1 | 90.3 | 115.7 |
| **Perimeter Noise** | **107.7** | **106.3** | **104.8** | **103.5** | **101.9** | **101.3** | **101.0** | **100.3** | **99.1** | **98.2** | **96.8** | **94.0** | **90.1** | **115.5** |
| **Average PN** | **108.6** | **106.7** | **104.6** | **103.4** | **102.2** | **101.9** | **101.6** | **100.8** | **99.6** | **99.0** | **98.0** | **94.7** | **90.0** | **115.8** |
| Wind Stream Noise | 116.7 | 115.7 | 114.1 | 112.8 | 110.9 | 109.3 | 107.8 | 106.6 | 105.9 | 105.4 | 104.4 | 101.4 | 97.0 | 123.9 |
| Wind Stream Noise | 111.5 | 109.9 | 108.7 | 107.3 | 106.4 | 104.9 | 104.2 | 100.7 | 100.2 | 98.9 | 97.5 | 95.1 | 91.5 | 119.9 |
| Wind Stream Noise | 116.4 | 115.1 | 114.1 | 112.9 | 111.7 | 110.3 | 108.6 | 106.2 | 103.8 | 101.6 | 99.9 | 99.1 | 98.5 | 123.5 |
| Wind Stream Noise | 116.6 | 116.1 | 115.0 | 113.9 | 112.8 | 111.3 | 109.5 | 107.0 | 104.5 | 102.1 | 100.3 | 99.8 | 99.5 | 124.0 |
| Wind Stream Noise | 115.0 | 112.9 | 111.4 | 109.8 | 108.6 | 106.9 | 104.6 | 104.0 | 102.7 | 101.5 | 100.1 | 97.3 | 95.0 | 122.0 |
| Wind Stream Noise | 116.9 | 115.7 | 113.9 | 112.6 | 110.9 | 109.4 | 108.1 | 106.8 | 106.1 | 105.5 | 103.6 | 100.0 | 97.2 | 124.0 |
| Wind Stream Noise | 111.9 | 110.3 | 109.2 | 107.3 | 106.1 | 104.1 | 101.9 | 101.0 | 100.0 | 98.8 | 96.5 | 93.5 | 91.0 | 119.9 |
| Wind Stream Noise | 114.3 | 113.0 | 111.5 | 110.0 | 108.4 | 106.9 | 105.5 | 103.3 | 101.4 | 99.5 | 98.6 | 98.5 | 97.9 | 121.3 |
| Wind Stream Noise | 116.5 | 115.8 | 114.7 | 113.7 | 112.6 | 111.1 | 109.4 | 107.0 | 104.5 | 102.0 | 100.2 | 99.2 | 98.8 | 123.8 |
| Wind Stream Noise | 115.7 | 113.8 | 112.3 | 109.8 | 108.0 | 107.2 | 105.6 | 103.5 | 103.0 | 102.0 | 100.4 | 97.9 | 95.6 | 122.5 |
| **Average WSN** | **115.2** | **113.8** | **112.5** | **111.0** | **109.6** | **108.1** | **106.5** | **104.6** | **103.2** | **101.7** | **100.2** | **98.2** | **96.2** | **122.5** |
| Standard HALO | 107.1 | 103.4 | 98.2 | 96.6 | 91.5 | 85.6 | 76.8 | 68.2 | 68.6 | 72.3 | 70.3 | 74.6 | 68.8 | 114.5 |
| Standard HALO | 101.9 | 99.6 | 95.6 | 95.1 | 90.0 | 83.0 | 72.6 | 63.1 | 63.6 | 67.3 | 65.2 | 69.9 | 65.1 | 109.3 |
| Standard HALO | 98.2 | 94.5 | 90.2 | 86.5 | 80.9 | 76.9 | 71.7 | 67.5 | 70.9 | 71.1 | 71.4 | 76.6 | 74.0 | 109.8 |
| Standard HALO | 98.2 | 94.5 | 90.3 | 86.6 | 81.4 | 77.7 | 72.5 | 70.0 | 70.9 | 69.1 | 69.7 | 76.3 | 74.8 | 109.7 |
| Standard HALO | 98.7 | 95.8 | 90.8 | 86.8 | 81.6 | 78.4 | 73.1 | 70.2 | 71.0 | 69.2 | 70.3 | 76.6 | 72.3 | 110.6 |
| Standard HALO | 100.9 | 97.8 | 93.7 | 93.4 | 88.8 | 83.2 | 73.9 | 66.1 | 66.8 | 71.5 | 72.5 | 76.7 | 69.2 | 109.7 |
| Standard HALO | 107.4 | 103.9 | 99.0 | 97.3 | 91.9 | 86.3 | 77.3 | 70.9 | 69.7 | 74.5 | 74.6 | 80.0 | 72.2 | 115.2 |
| Standard HALO | 103.2 | 101.1 | 98.2 | 95.1 | 91.7 | 83.7 | 73.8 | 65.8 | 72.9 | 67.9 | 67.4 | 69.9 | 69.1 | 111.2 |
| Standard HALO | 97.7 | 97.6 | 96.4 | 93.9 | 89.6 | 81.4 | 72.0 | 64.8 | 72.0 | 66.7 | 66.7 | 68.1 | 67.6 | 105.6 |
| Standard HALO | 95.1 | 93.4 | 91.0 | 87.8 | 86.7 | 80.2 | 77.5 | 71.8 | 73.1 | 73.4 | 71.4 | 73.3 | 73.2 | 105.6 |
| Standard HALO | 100.8 | 99.0 | 96.3 | 93.4 | 90.4 | 86.4 | 87.3 | 87.8 | 85.7 | 82.3 | 86.9 | 80.9 | 76.8 | 110.6 |
| Standard HALO | 101.0 | 98.3 | 95.9 | 91.9 | 88.9 | 85.0 | 87.2 | 87.7 | 86.4 | 83.0 | 86.6 | 80.0 | 75.9 | 111.1 |
| Standard HALO | 97.7 | 95.7 | 94.1 | 91.8 | 88.8 | 81.4 | 74.1 | 70.1 | 72.6 | 68.1 | 69.9 | 71.5 | 67.7 | 105.8 |
| Standard HALO | 104.0 | 102.0 | 99.2 | 95.6 | 91.3 | 84.8 | 74.6 | 68.3 | 72.1 | 68.3 | 69.4 | 72.1 | 68.9 | 112.1 |
| **Avg: Standard HALO** | **100.9** | **98.3** | **94.9** | **92.3** | **88.1** | **82.4** | **76.0** | **70.9** | **72.6** | **71.8** | **72.3** | **74.8** | **71.1** | **110.1** |

Third-octave center frequency and A-weighted noise levels (dBA) for all conditions in the Vertical Wind Tunnel.

| | Third-octave center frequency (Hz) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Condition** | **25** | **31.5** | **40** | **50** | **63** | **80** | **100** | **125** | **160** | **200** | **250** | **315** | **400** | **500** |
| Modified HALO | 100.0 | 96.3 | 99.8 | 90.4 | 93.1 | 102.4 | 116.8 | 104.4 | 108.6 | 113.8 | 114.3 | 116.2 | 113.8 | 108.7 |
| Modified HALO | 108.9 | 110.8 | 112.3 | 110.7 | 111.4 | 110.0 | 120.6 | 109.1 | 106.9 | 113.1 | 106.6 | 108.8 | 103.7 | 101.1 |
| Modified HALO | 114.5 | 117.5 | 120.2 | 120.2 | 116.9 | 115.6 | 119.9 | 113.4 | 111.5 | 114.6 | 109.1 | 108.9 | 105.0 | 100.6 |
| Modified HALO | 115.3 | 115.5 | 121.8 | 122.0 | 117.1 | 116.3 | 119.7 | 113.1 | 112.3 | 114.7 | 109.4 | 109.1 | 105.6 | 101.2 |
| Modified HALO | 100.8 | 98.1 | 101.3 | 87.9 | 91.0 | 109.5 | 116.3 | 104.1 | 111.0 | 113.8 | 113.7 | 113.8 | 112.0 | 107.4 |
| Modified HALO | 86.9 | 86.6 | 91.2 | 86.7 | 88.9 | 98.3 | 113.0 | 102.8 | 108.1 | 113.7 | 114.4 | 116.5 | 115.0 | 111.7 |
| Modified HALO | 92.3 | 95.3 | 98.6 | 103.2 | 100.8 | 101.2 | 115.5 | 103.1 | 101.7 | 110.1 | 102.7 | 104.9 | 102.0 | 100.8 |
| Modified HALO | 102.8 | 109.6 | 111.2 | 111.0 | 110.1 | 110.5 | 118.6 | 111.3 | 110.0 | 116.1 | 110.1 | 110.4 | 106.9 | 103.7 |
| Modified HALO | 106.3 | 108.7 | 112.6 | 112.8 | 111.5 | 112.5 | 119.1 | 110.8 | 110.1 | 116.9 | 110.3 | 111.6 | 109.0 | 105.8 |
| Modified HALO | 86.9 | 87.6 | 91.5 | 84.4 | 87.5 | 105.4 | 113.4 | 102.6 | 110.5 | 113.7 | 114.2 | 114.7 | 113.2 | 110.7 |
| **Avg: Modified HALO** | **101.5** | **102.6** | **106.1** | **102.9** | **102.8** | **108.2** | **117.3** | **107.5** | **109.1** | **114.1** | **110.5** | **111.5** | **108.6** | **105.2** |
| HALO with ANR | 101.7 | 99.5 | 101.8 | 93.7 | 97.2 | 107.4 | 121.0 | 106.7 | 108.0 | 112.3 | 108.0 | 107.3 | 103.5 | 101.1 |
| HALO with ANR | 106.6 | 109.9 | 111.4 | 110.1 | 109.7 | 110.9 | 124.6 | 112.2 | 108.0 | 113.6 | 105.1 | 107.1 | 100.4 | 95.3 |
| HALO with ANR | 115.9 | 119.5 | 123.3 | 122.3 | 116.7 | 115.1 | 116.7 | 113.5 | 110.9 | 109.0 | 105.3 | 101.4 | 99.1 | 95.1 |
| HALO with ANR | 116.9 | 120.2 | 122.3 | 123.2 | 118.1 | 116.2 | 117.2 | 113.6 | 111.6 | 109.0 | 105.7 | 101.6 | 99.4 | 95.5 |
| HALO with ANR | 116.7 | 120.7 | 124.6 | 123.8 | 117.9 | 116.4 | 117.6 | 114.4 | 112.3 | 110.8 | 106.8 | 103.6 | 100.6 | 96.8 |
| HALO with ANR | 80.6 | 79.6 | 82.6 | 75.8 | 79.4 | 91.1 | 106.4 | 91.4 | 95.8 | 102.1 | 99.4 | 102.5 | 98.9 | 100.1 |
| HALO with ANR | 98.4 | 102.8 | 107.6 | 108.5 | 108.8 | 109.8 | 111.4 | 104.6 | 100.5 | 105.1 | 96.6 | 99.6 | 93.6 | 92.9 |
| HALO with ANR | 104.3 | 107.4 | 116.4 | 115.9 | 111.4 | 111.2 | 113.9 | 109.6 | 107.5 | 108.3 | 102.2 | 99.3 | 96.8 | 95.4 |
| HALO with ANR | 105.5 | 111.1 | 115.3 | 116.7 | 110.9 | 109.5 | 113.6 | 109.2 | 106.9 | 107.7 | 101.9 | 99.6 | 97.6 | 95.6 |
| HALO with ANR | 106.7 | 111.7 | 118.2 | 118.7 | 111.5 | 110.9 | 113.7 | 110.3 | 107.4 | 108.5 | 103.1 | 100.3 | 98.1 | 96.7 |
| **Avg: HALO ANR** | **105.3** | **108.2** | **112.4** | **110.9** | **108.2** | **109.9** | **115.6** | **108.6** | **106.9** | **108.6** | **103.4** | **102.2** | **98.8** | **96.5** |
| Standard Z1 | 100.0 | 97.8 | 97.8 | 94.9 | 97.3 | 107.8 | 113.2 | 105.5 | 117.1 | 120.8 | 115.4 | 114.7 | 116.3 | 115.1 |
| Standard Z1 | 110.9 | 112.1 | 113.9 | 113.6 | 112.7 | 111.9 | 121.6 | 112.5 | 111.4 | 117.8 | 112.1 | 114.7 | 113.3 | 111.9 |
| Standard Z1 | 110.3 | 112.0 | 116.1 | 116.8 | 113.3 | 112.9 | 122.7 | 114.0 | 113.0 | 118.4 | 112.3 | 115.0 | 113.8 | 111.5 |
| Standard Z1 | 109.3 | 110.3 | 114.8 | 115.1 | 112.1 | 114.0 | 122.2 | 113.2 | 112.2 | 119.5 | 112.2 | 115.0 | 113.8 | 111.7 |
| Standard Z1 | 112.5 | 115.2 | 116.9 | 116.9 | 114.1 | 114.8 | 119.4 | 113.9 | 113.6 | 119.3 | 113.6 | 115.5 | 114.2 | 112.7 |
| Standard Z1 | 98.7 | 96.8 | 99.5 | 96.3 | 98.4 | 102.6 | 114.2 | 106.6 | 111.1 | 117.5 | 116.7 | 118.6 | 119.4 | 118.6 |
| Standard Z1 | 90.5 | 90.7 | 92.4 | 91.8 | 94.6 | 103.4 | 108.9 | 102.5 | 115.8 | 120.3 | 114.8 | 114.3 | 115.7 | 115.5 |
| Standard Z1 | 94.9 | 98.9 | 105.7 | 105.0 | 106.3 | 108.9 | 118.6 | 111.7 | 112.0 | 117.3 | 113.7 | 116.5 | 114.3 | 113.6 |
| Standard Z1 | 96.8 | 100.8 | 105.8 | 106.3 | 106.0 | 108.0 | 119.5 | 110.9 | 110.1 | 118.4 | 111.1 | 115.1 | 113.1 | 112.2 |
| Standard Z1 | 97.3 | 101.8 | 107.9 | 106.1 | 105.7 | 108.6 | 118.9 | 111.4 | 111.7 | 119.3 | 112.3 | 115.2 | 113.7 | 112.9 |
| Standard Z1 | 97.9 | 102.5 | 107.2 | 109.4 | 108.9 | 110.7 | 117.0 | 113.1 | 114.0 | 119.3 | 114.4 | 116.1 | 115.9 | 114.4 |
| Standard Z1 | 91.7 | 93.2 | 95.1 | 94.8 | 96.1 | 99.5 | 109.7 | 104.1 | 109.0 | 116.6 | 116.2 | 118.4 | 118.9 | 118.5 |
| **Avg: Standard Z1** | **100.9** | **102.7** | **106.1** | **105.6** | **105.5** | **108.6** | **117.2** | **110.0** | **112.6** | **118.7** | **113.7** | **115.8** | **115.2** | **114.1** |

Third-octave center frequency and A-weighted noise levels (dBA) for all conditions in the Vertical Wind Tunnel.

| | Third-octave center frequency (Hz) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Condition** | **630** | **800** | **1k** | **1.25k** | **1.6k** | **2k** | **2.5k** | **3.15k** | **4k** | **5k** | **6.3k** | **8k** | **10k** | **AWT** |
| Modified HALO | 102.9 | 97.6 | 93.2 | 88.3 | 81.7 | 74.4 | 70.4 | 67.2 | 68.6 | 70.3 | 69.2 | 67.1 | 62.9 | 114.7 |
| Modified HALO | 95.8 | 89.7 | 85.7 | 81.2 | 74.6 | 67.9 | 65.8 | 62.9 | 61.6 | 63.6 | 63.3 | 60.1 | 59.7 | 108.8 |
| Modified HALO | 95.9 | 91.3 | 87.7 | 84.0 | 79.5 | 75.0 | 72.1 | 69.0 | 66.7 | 67.9 | 66.8 | 65.5 | 63.5 | 110.0 |
| Modified HALO | 96.1 | 92.2 | 88.4 | 85.4 | 81.0 | 76.2 | 73.2 | 70.2 | 68.5 | 69.6 | 69.2 | 67.9 | 64.6 | 110.3 |
| Modified HALO | 101.2 | 95.7 | 91.1 | 86.4 | 79.6 | 72.8 | 69.1 | 66.9 | 68.3 | 70.2 | 66.3 | 62.9 | 61.0 | 113.2 |
| Modified HALO | 107.0 | 102.2 | 97.7 | 93.0 | 84.5 | 76.2 | 72.9 | 70.7 | 75.3 | 77.1 | 72.7 | 65.9 | 61.1 | 115.9 |
| Modified HALO | 98.0 | 93.0 | 89.3 | 84.2 | 75.9 | 66.0 | 63.1 | 61.4 | 62.1 | 64.8 | 64.9 | 61.2 | 59.8 | 106.2 |
| Modified HALO | 99.8 | 95.0 | 90.8 | 85.8 | 79.5 | 73.9 | 72.1 | 69.9 | 70.9 | 72.7 | 69.5 | 66.8 | 62.0 | 111.1 |
| Modified HALO | 101.3 | 96.9 | 92.7 | 88.4 | 82.3 | 77.5 | 75.4 | 73.8 | 75.1 | 75.3 | 73.6 | 70.6 | 64.7 | 112.2 |
| Modified HALO | 105.6 | 101.1 | 96.1 | 91.7 | 83.4 | 74.9 | 70.4 | 68.2 | 74.5 | 78.3 | 75.0 | 70.2 | 64.3 | 114.7 |
| **Avg: Modified HALO** | **100.4** | **95.5** | **91.3** | **86.8** | **80.2** | **73.5** | **70.5** | **68.0** | **69.2** | **71.0** | **69.1** | **65.8** | **62.4** | **111.7** |
| HALO with ANR | 98.9 | 92.5 | 88.0 | 86.2 | 81.6 | 80.1 | 77.4 | 74.2 | 72.3 | 70.8 | 65.1 | 59.5 | 60.0 | 108.8 |
| HALO with ANR | 92.9 | 87.3 | 82.7 | 80.3 | 76.6 | 77.0 | 76.8 | 74.8 | 73.5 | 71.8 | 65.6 | 61.7 | 59.6 | 109.3 |
| HALO with ANR | 91.7 | 88.0 | 85.4 | 84.5 | 80.2 | 74.0 | 70.2 | 66.9 | 65.2 | 63.7 | 61.3 | 62.1 | 64.2 | 106.3 |
| HALO with ANR | 91.7 | 88.7 | 86.3 | 85.5 | 80.9 | 75.0 | 71.4 | 68.0 | 66.2 | 65.3 | 63.0 | 65.0 | 66.1 | 106.7 |
| HALO with ANR | 93.3 | 89.9 | 86.9 | 84.1 | 80.7 | 76.6 | 73.9 | 70.3 | 69.6 | 68.6 | 64.3 | 62.2 | 60.5 | 107.7 |
| HALO with ANR | 97.1 | 91.2 | 83.5 | 82.8 | 79.7 | 74.1 | 71.1 | 66.6 | 64.1 | 63.7 | 65.3 | 60.9 | 59.8 | 102.9 |
| HALO with ANR | 91.3 | 85.3 | 76.9 | 75.8 | 73.1 | 70.3 | 70.0 | 66.5 | 65.7 | 63.6 | 65.4 | 61.1 | 59.8 | 100.8 |
| HALO with ANR | 92.8 | 88.4 | 81.7 | 82.1 | 80.0 | 75.6 | 74.1 | 67.5 | 65.0 | 63.7 | 63.4 | 60.1 | 59.9 | 103.9 |
| HALO with ANR | 92.9 | 87.9 | 81.6 | 82.5 | 79.6 | 75.4 | 73.5 | 67.3 | 65.2 | 64.2 | 62.3 | 60.0 | 60.2 | 103.7 |
| HALO with ANR | 94.1 | 89.5 | 82.3 | 81.5 | 80.3 | 76.5 | 73.8 | 67.6 | 65.5 | 64.6 | 62.3 | 60.4 | 60.0 | 104.5 |
| **Avg: HALO ANR** | **93.7** | **88.9** | **83.5** | **82.5** | **79.3** | **75.5** | **73.2** | **69.0** | **67.2** | **66.0** | **63.8** | **61.3** | **61.0** | **105.5** |
| Standard Z1 | 113.8 | 111.8 | 108.2 | 103.9 | 101.5 | 99.5 | 96.8 | 93.0 | 89.9 | 87.9 | 85.9 | 82.5 | 76.8 | 119.8 |
| Standard Z1 | 111.3 | 108.4 | 104.2 | 100.3 | 97.6 | 95.9 | 94.3 | 90.9 | 88.0 | 86.3 | 84.3 | 81.3 | 75.9 | 117.1 |
| Standard Z1 | 111.0 | 108.5 | 104.2 | 100.0 | 97.2 | 95.0 | 93.5 | 90.7 | 87.9 | 85.7 | 83.2 | 80.5 | 75.1 | 117.2 |
| Standard Z1 | 110.8 | 108.4 | 104.2 | 100.1 | 97.0 | 95.0 | 93.6 | 90.8 | 87.5 | 85.1 | 83.9 | 80.9 | 76.3 | 117.3 |
| Standard Z1 | 111.7 | 109.1 | 105.1 | 101.5 | 98.4 | 96.7 | 95.3 | 92.2 | 89.2 | 87.3 | 85.6 | 82.7 | 77.5 | 117.9 |
| Standard Z1 | 117.4 | 115.1 | 111.5 | 108.1 | 105.5 | 103.3 | 100.5 | 96.4 | 93.2 | 91.2 | 89.9 | 87.1 | 81.4 | 122.7 |
| Standard Z1 | 115.0 | 113.2 | 110.1 | 107.1 | 104.4 | 102.3 | 100.0 | 94.9 | 86.5 | 87.4 | 88.0 | 78.3 | 72.6 | 120.5 |
| Standard Z1 | 112.9 | 110.2 | 107.2 | 104.1 | 101.7 | 100.1 | 98.5 | 94.1 | 87.1 | 86.9 | 88.0 | 81.3 | 74.1 | 118.7 |
| Standard Z1 | 112.4 | 110.3 | 106.5 | 103.3 | 100.8 | 99.2 | 98.4 | 94.3 | 85.4 | 84.9 | 87.1 | 80.7 | 71.1 | 117.9 |
| Standard Z1 | 112.6 | 110.6 | 107.2 | 103.5 | 100.9 | 98.8 | 97.7 | 93.5 | 86.1 | 86.2 | 87.3 | 79.6 | 74.0 | 118.4 |
| Standard Z1 | 113.9 | 111.8 | 109.2 | 106.4 | 104.0 | 101.8 | 99.6 | 95.6 | 90.1 | 88.8 | 88.1 | 81.9 | 76.7 | 119.9 |
| Standard Z1 | 117.6 | 115.9 | 113.1 | 110.2 | 107.2 | 104.8 | 101.8 | 96.8 | 91.7 | 89.9 | 89.2 | 81.3 | 77.4 | 123.0 |
| **Avg: Standard Z1** | **113.4** | **111.1** | **107.6** | **104.0** | **101.4** | **99.4** | **97.5** | **93.6** | **88.6** | **87.3** | **86.7** | **81.5** | **75.7** | **119.2** |

Third-octave center frequency and A-weighted noise levels (dBA) for all conditions in the Vertical Wind Tunnel.

| | Third-octave center frequency (Hz) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Condition** | **25** | **31.5** | **40** | **50** | **63** | **80** | **100** | **125** | **160** | **200** | **250** | **315** | **400** | **500** |
| Z1 Modified | 101.7 | 99.6 | 100.3 | 95.6 | 94.3 | 106.5 | 112.4 | 104.8 | 113.8 | 117.2 | 113.0 | 112.8 | 112.1 | 110.4 |
| Z1 Modified | 102.0 | 96.0 | 96.7 | 91.4 | 93.1 | 102.8 | 124.4 | 108.2 | 105.2 | 112.7 | 102.8 | 106.6 | 104.5 | 103.2 |
| Z1 Modified | 115.4 | 115.4 | 120.1 | 122.0 | 118.7 | 117.3 | 119.5 | 117.0 | 116.9 | 119.5 | 113.3 | 112.4 | 109.4 | 107.0 |
| Z1 Modified | 114.4 | 116.3 | 117.2 | 119.6 | 117.1 | 115.1 | 120.1 | 114.8 | 113.3 | 116.6 | 110.2 | 110.7 | 107.6 | 105.1 |
| Z1 Modified | 115.6 | 119.6 | 122.7 | 126.0 | 122.3 | 117.1 | 118.3 | 116.0 | 114.9 | 115.0 | 111.4 | 110.0 | 107.0 | 104.7 |
| Z1 Modified | 100.1 | 96.4 | 97.7 | 87.5 | 91.4 | 108.9 | 113.7 | 106.1 | 112.2 | 114.1 | 113.4 | 112.8 | 112.9 | 110.9 |
| Z1 Modified | 88.1 | 88.2 | 90.7 | 88.3 | 89.0 | 101.6 | 108.9 | 102.4 | 112.4 | 116.8 | 112.4 | 112.4 | 111.0 | 109.9 |
| Z1 Modified | 88.4 | 84.6 | 88.3 | 83.9 | 85.9 | 99.2 | 121.6 | 106.8 | 104.3 | 114.1 | 101.2 | 107.7 | 102.9 | 104.3 |
| Z1 Modified | 102.1 | 104.3 | 110.1 | 115.1 | 115.9 | 115.1 | 117.7 | 116.2 | 116.0 | 119.1 | 113.0 | 112.4 | 109.4 | 107.8 |
| Z1 Modified | 100.7 | 106.2 | 108.5 | 113.5 | 112.5 | 111.6 | 117.6 | 112.9 | 112.3 | 116.3 | 109.4 | 110.7 | 106.5 | 105.0 |
| Z1 Modified | 103.5 | 109.1 | 115.6 | 120.7 | 118.8 | 114.7 | 117.1 | 113.1 | 113.2 | 116.3 | 110.4 | 109.4 | 106.7 | 105.3 |
| Z1 Modified | 85.8 | 85.1 | 87.1 | 81.1 | 85.3 | 102.8 | 109.5 | 103.6 | 111.1 | 113.0 | 112.4 | 112.4 | 111.7 | 110.1 |
| **Avg:Modified Z1** | **101.5** | **101.7** | **104.6** | **103.7** | **103.7** | **109.4** | **116.7** | **110.2** | **112.1** | **115.9** | **110.2** | **110.9** | **108.5** | **107.0** |

| | Third-octave center frequency (Hz) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Condition** | **630** | **800** | **1k** | **1.25k** | **1.6k** | **2k** | **2.5k** | **3.15k** | **4k** | **5k** | **6.3k** | **8k** | **10k** | **AWT** |
| Z1 Modified | 107.2 | 103.6 | 99.4 | 94.4 | 87.8 | 81.6 | 75.8 | 70.1 | 66.8 | 65.1 | 62.3 | 60.1 | 59.5 | 114.7 |
| Z1 Modified | 103.2 | 99.0 | 93.4 | 88.4 | 81.4 | 75.5 | 70.8 | 66.3 | 63.4 | 62.2 | 61.1 | 59.8 | 59.2 | 110.3 |
| Z1 Modified | 104.7 | 101.0 | 96.5 | 91.8 | 87.3 | 83.4 | 80.0 | 76.6 | 73.8 | 73.1 | 71.9 | 69.4 | 65.3 | 114.5 |
| Z1 Modified | 102.4 | 98.8 | 94.5 | 89.6 | 84.4 | 80.2 | 76.7 | 74.1 | 72.6 | 72.1 | 70.3 | 67.4 | 62.7 | 112.2 |
| Z1 Modified | 102.3 | 98.9 | 94.7 | 90.5 | 85.8 | 81.6 | 77.9 | 74.4 | 71.7 | 69.6 | 67.5 | 64.7 | 61.6 | 112.1 |
| Z1 Modified | 108.9 | 104.9 | 100.8 | 96.4 | 90.1 | 83.2 | 77.0 | 71.9 | 68.1 | 67.1 | 63.8 | 61.0 | 59.6 | 115.1 |
| Z1 Modified | 107.5 | 105.7 | 104.4 | 100.7 | 94.1 | 86.9 | 80.5 | 75.5 | 71.2 | 69.0 | 66.6 | 64.6 | 61.9 | 114.9 |
| Z1 Modified | 102.4 | 100.1 | 98.2 | 94.6 | 88.2 | 81.9 | 76.5 | 71.7 | 68.7 | 66.9 | 66.0 | 64.1 | 61.5 | 110.2 |
| Z1 Modified | 106.5 | 105.1 | 102.9 | 99.5 | 94.7 | 90.0 | 86.3 | 83.4 | 82.7 | 80.5 | 76.1 | 71.2 | 66.8 | 115.0 |
| Z1 Modified | 104.0 | 102.4 | 100.5 | 96.8 | 91.8 | 86.8 | 82.9 | 79.8 | 79.4 | 77.7 | 73.6 | 69.0 | 64.6 | 112.4 |
| Z1 Modified | 104.3 | 102.4 | 100.0 | 95.3 | 89.3 | 82.8 | 77.7 | 73.6 | 69.9 | 67.9 | 66.5 | 63.8 | 61.8 | 112.4 |
| Z1 Modified | 108.8 | 107.1 | 106.3 | 102.9 | 96.7 | 89.7 | 84.1 | 79.4 | 75.0 | 71.2 | 67.8 | 65.0 | 61.6 | 115.4 |
| **Avg:Modified Z1** | **105.2** | **102.4** | **99.3** | **95.1** | **89.3** | **83.6** | **78.9** | **74.7** | **71.9** | **70.2** | **67.8** | **65.0** | **62.2** | **113.3** |